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CERTIFICATE

This certificate is issued in support of an application for Patent registration in a country outside New Zealand pursuant to the Patents Act 1953 and the Regulations thereunder.

I hereby certify that the annexed is a true copy of the Provisional Specification as filed on 24 August 1998 with an application for Letters Patent number 331527 made by Carter Holt Harvey Ltd.

I further certify that pursuant to a claim filed on 24 August 1999 under Section 24(1) of the Patents Act 1953, a direction was given that the application proceed in the name of CARTER HOLT HARVEY LTD trading as CARTER HOLT HARVEY HARVEY PULP & PAPER and CANTERPRISE LIMITED by virtue of a deed dated 19 August 1999.

Dated 30 September 1999.

Neville Harris

Neville Harris
Commissioner of Patents

Patents Form No. 4

Our Ref: JM502302

Patents Act 1953

PROVISIONAL SPECIFICATION

METHOD OF SELECTING AND/OR PROCESSING WOOD ACCORDING TO FIBRE CHARACTERISTICS

We, **CARTER HOLT HARVEY LTD Trading As CARTER HOLT HARVEY PULP & PAPER**, a New Zealand company, of 640 Great South Road, Manukau City, Auckland, New Zealand, do hereby declare this invention to be described in the following statement:

JM:RM:PT0431117

TECHNICAL FIELD

This invention relates to the use of acoustic wave testing of logs in the selection of wood for purposes for which fibre length and/or strength characteristics are important. The invention has particular application to the pulp and paper industry.

BACKGROUND

Log segregation is an important issue for the forestry and wood products industries given the variable nature of the raw material and the unique set of properties required in different end products. At present, historical wood density information and a general knowledge of trends in fibre properties in different parts of the tree, are the only tools available to perform some limited segregation of wood for pulp and paper manufacture. Basic density has several short-comings; it is difficult to measure (taking several days to get a result); it is correlated with fibre properties only at a population level and so cannot be applied at an individual tree or log level.

The measurement of velocity of sound in a log is a non-destructive technique which evaluates the stiffness of wood (or other materials) by means of sound transmission. The sound wave, for instance induced by the impact of a hammer at one end, travels down the length of a log. The transit time (Δt) is measured. The modulus of elasticity (MOE) is computed from the transit time and density (p) as follows:

$$\mathrm{MOE} = V^2 p = (l/\Delta t)^2 p$$

This is a fundamental relationship for materials. Although a log of wood is not a homogeneous material (compared with an iron bar, for example), and does not obey this law perfectly, relatively good relationships have been found between sound wave speed and the average measured stiffness (MOE) of timber which is sawn from the log (where MOE is independently measured in a three-point bending test).

The use of velocity of sound measurement for the grading of wood is described in United States patent specification no. 1,244,699, dating back to 1968.

The characteristics measured in that patent were modulus of elasticity from which could be calculated a grade of modulus of rupture tension. These mechanical properties could be related to the structural strength of lengths of timber.

The measurement of velocity of sound in a log can be made with industrial stress wave timers, which are commercially available. Henceforth, the term 'stress wave timer' will be used to refer to devices which can measure the velocity of sound in a log of wood. Their beneficial use in log sorting is still considered commercially unproven despite the 30 years or more since their first trialing.

Log segregation is an important issue for the forestry and wood products industry, since the raw material (for example, radiata pine trees) is highly variable in properties due to genetic differences, silvicultural differences, and geographical and site differences. Hence, some logs are more suitable for structural timber, for example, than are others and it is important to send the right logs to the right processing facility.

Even within a tree there are differences in wood properties between the corewood of the tree and the outer wood, and also variations from the bottom to the top of the tree, which further complicates the wood segregation issue. Thus, there are major commercial benefits to be gained by optimising the use of the wood resource for different solid, reconstituted, and pulp and paper products, which may each require different properties in the raw material.

Little information on wood quality at an individual stand level is available, other than average wood density data from historical measurements, and there is generally no information at all at an individual tree level. To date, basic wood density is the only tool available. Most wood properties are related to the basic density of the wood (i.e. the amount of dry wood substance per unit volume of wood). But basic density is a difficult measurement to make and impossible to usefully apply at a whole tree level.

Furthermore, density is a measure of the amount of wood substance and void space in a unit volume of wood, but is not indicative of the number of fibres which make up that space. For example, individual trees can have roughly the same chip basic density, but have very different fibre lengths, fibre width and thicknesses, fibre wall areas (coarseness), and numbers of fibres per unit mass of wood.

Pulp and paper mills normally utilise the residues from harvesting (top logs and low grade logs that arise during harvesting operations) and from saw milling, such as chips from the slabwood sawn from the outsides of the log.

Some wood segregation on the basis of basic density is practiced in pulp and paper manufacture. High density wood from the outside of the tree (the slabwood) generally has long and coarse (thicker-walled) fibres which are suitable for certain products such as cement-board reinforcing pulp and sack grades. Wood from the top of the tree is more like corewood and has lower density with shorter, thinner walled (low coarseness) fibres. Pulp from this wood is more suitable for printing and writing or tissue grade papers, for example.

However, basic density is a very crude basis for wood segregation and knowledge of density variability is rather poor.

Softwood kraft pulp qualities are normally determined by the handsheet properties of apparent density or bulk, tensile strength, and out-of-plane tear strength. Fibre length is the critical softwood kraft pulp fibre determinant. With too little fibre length such pulps lose their characteristic softwood reinforcement properties. However, very long, coarse fibres can be difficult to refine and are prone to flocculation and sheet formation becomes a problem. Other fibre properties are also important but only after fibre length requirements are met. Fibre length is critical for the reinforcement properties of softwood kraft pulps. If pulp fibre length falls below a certain critical level of about 2.0 – 2.1mm, bulk is abruptly decreased and reinforcement tear/tensile strengths are correspondingly, abruptly lowered.

The Wet Zero Span Tensile (WZST) strength of a pulp is influenced by the number of fibres per unit mass of pulp and by the strength of the individual fibres. Individual fibre strength is, in turn, influenced by fibre coarseness and intra-fibrewall characteristics such as micro-fibril angle (MFA). WZST strength is a good predictor of Tear Index at a given Tensile Index, the traditional indicator of softwood kraft reinforcement potential.

Pulp quality is very much a function of its end-use. As well as the above mentioned quality factors, end-users of market pulps are also concerned about: ease of beating – the amount of energy required to refine a pulp to an acceptable tensile strength; reinforcement potential; and effects on paper sheet formation.

Whilst it is known to use stress wave timers to identify characteristics relating to solid wood stiffness, such apparatus has not been used to determine characteristics associated with timber used in the pulp and paper industry. Moreover, the properties which determine allocation of wood to particular product manufacture in the pulp and paper industry, namely fibre length and pulp strength, are quite different from the mechanical strength properties used to characterise solid timber.

It is an object of the present invention to provide a method of selecting and/or processing wood according to fibre characteristics which reduces or overcomes the abovementioned problems, or which at least provides the public with a useful alternative.

Other objects of the present invention may become apparent from the following description which is given by way of example only.

SUMMARY OF INVENTION

According to one aspect of the present invention there is provided a method of selecting wood for use in pulp and paper manufacture, the method including the steps of:

- acoustic wave testing logs to measure the velocity of sound through the wood, and
- allocating the wood for a specified pulp and paper process in accordance with the measured velocity of sound.

According to a further aspect of the present invention there is provided a method of selecting wood according to fibre characteristics, the method including the steps of:

- acoustic wave testing logs to measure the velocity of sound through the wood,
- calculating the properties of average fibre length and/or pulp strength from the velocity of sound measured, and
- allocating the wood for a specified pulp and paper process in accordance with the calculated property or properties.

According to a further aspect of the present invention there is provided a method of processing wood for use in pulp and paper manufacture, the method including the steps of:

- measuring the velocity of sound through wood,
- selecting wood for which the measured velocity of sound is within a selected range, and
- pulping the selected wood for use in the manufacture of a product for which the selected range of velocity of sound correlates with preferred wood characteristics for that product.

Preferably, the preferred wood characteristics may be the expected pulp average fibre length and/or pulp strength.

According to a further aspect of the invention there is provided use of acoustic wave testing in the selection of wood according to fibre characteristics.

According to a further aspect of the present invention there is provided use of acoustic wave testing in the selection of wood for pulping according to preferred wood characteristics for use in the manufacture of products from pulp.

According to a still further aspect of the present invention there is provided use of acoustic wave testing to identify preferred wood characteristics which make the wood most suitable for use in the manufacture of selected products from pulp.

Preferably, the preferred wood characteristics may include expected pulp average fibre length and/or pulp strength.

According to a further aspect of the present invention there is provided a method of selecting and/or processing wood substantially as herein described and with reference to the accompanying Figures and/or examples.

According to a further aspect of the present invention there is provided apparatus for carrying out a method of the present invention substantially as herein described and with reference to the accompanying Figures and/or examples.

Other aspects of the present invention may become apparent from the following description which is given by way of example only.

BRIEF DESCRIPTION OF FIGURES

Figure 1: shows a schematic representation of the source of material for a pulp mill;

Figure 2: shows a schematic representation of the commercial application of the method of the invention at a pulp mill.

DETAILED DESCRIPTION OF INVENTION

A method of sorting or processing wood of the present invention may employ a conventional stress wave timer. Appropriate apparatus to carry out the

measurement of velocity of sound through a log will be familiar to a person skilled in the art, as will the operation of a stress wave timer to record sound velocities.

The following description is given with reference to the production of kraft pulp. It will be appreciated, however, that the method of the invention is not restricted to just kraft pulp production, but may equally be applicable to the selection of wood for other types of pulping, and indeed for wood-fibre-based processes other than pulp and paper manufacture.

Figure 1 is a schematic representation of the source of primary material for a pulp and paper mill. Velocity of sound may be recorded for logs as they are received at a pulp and paper mill prior to processing. Alternatively, logging companies could measure the velocity of sound through whole logs such that whole logs and/or slabwood in the form of sawmill wood chips could be selected for subsequent pulping according to the sound characteristics of the logs. Results of the data recorded for each log may then be used to determine approximate expected average pulp fibre length and pulp strength characteristics for pulp if formed from that log or slabwood portion of the log by comparison of the data with correlations for velocity of sound with average pulp fibre length or pulp strength. For example using computing means.

Logs having velocity of sound characteristics within specified ranges may be identified by an identification means so that each log or the slabwood arising from a sawn log is allocated to a batch for use in the manufacture of a particular pulped product.

For example, wood producing pulp having a shorter length weighted average fibre length (LWFL) and a lower WZST strength is preferred for use in the manufacture of very high density papers such as release papers and glassine. High LWFL and WZST strength pulp is most appropriately used for very high tearing strength grades of paper. such as fibre-cement grades. Table I shows preferred end-use applications for radiata pine wood producing kraft pulp having specified fibre-length/pulp properties.

The effectiveness of the method of the present invention for sorting/processing of wood in the pulp and paper industry was investigated in a study involving 250 logs of radiata pine taken randomly from a timber mill. The logs were peeled to expose the corewood at the centre of the log. Each peeler core was tested for speed of sound, before samples from each log were taken for subsequent measurement of key pulp and paper properties.

The peeler cores, and their corresponding discs removed for pulping, were divided into classes with respect to sound speed. The sound speeds varied from 1.44 to 4.16 x 10^3 m/s, and the population of peeler cores was divided into classes at 0.157 x 10^3 m/s intervals, giving a total of 18 sound classes, each containing between 2 and 34 peeler core samples.

The samples for each sound speed class were grouped, chipped and pulped. The half scale Kappa number of each pulp was tested to ensure that it had been delignified sufficiently, and if so hand sheets were formed for measurement of WZST strength, internal tearing resistance and tensile/stretch characteristics. In addition fibre length measurements were taken using a Kajaani FS-200 Fibre Analyser. Length weighted average fibre length (LWFL) and weight weighted average fibre length (WWFL) were calculated.

The average velocity of sound and the number of peeler cores in each class are shown in Table II. The distribution for the 18 sound classes was close to normal.

Large variations in both average fibre length and pulp strength were observed across the 18 sound classes of wood. This was an unexpected and surprising result given that the sample population of 250 samples all contained only corewood. The average fibre length ranged from 1.77 to 2.78mm LWFL, whilst the average pulp strength ranged from 9.92 to 16.54km WZST.

Table I: Radiata Pine Kraft Pulp Properties versus End-Use Applications

Average LWFL (mm)	Coarseness (mg/m)	Fibres/g o.d. pulp (relative)	WZST Strength (km)	Refining Response	End-use (examples)
1.80 – 2.00	0.16	100	10 – 11	beats easily to form high density sheets of relatively low tensile strength	very high density papers e.g. release papers and glassine
2.00 – 2.20	0.18	86	11 – 12	beats easily to form sheets of high density with moderate tensile strength	good for reinforcement in products requiring low coarseness fibres, for example in some tissue grades
2.20 – 2.40	0.20	69	12 – 14	moderately easy to beat forming sheets of intermediate density with good tensile strength	excellent for reinforcement component of printing and writing grades (fine papers)
2.40 – 2.60	0.23	54	14 – 16	medium – high coarseness fibres with good tearing strengths; slower beating response	suitable for manufacture of products which value high tearing strength, such as some packaging grades
>2.60	0.26	44	16 – 17	long, coarse fibres that are difficult to refine forming bulky sheets	very high tearing strength, suitable for some specialty grades, such as for fibre-cement board manufacture, and for papers of high bulk

A strong correlation was identified between sound speed vs fibre length (R^2 of 89%) and sound speed vs WZST strength (R^2 of 93%), as shown in Graphs 1 and 2, respectively.

The strong correlation between average LWFL and sound speed was considered quite remarkable, as was the distinct difference between the fibre length distributions for the different sound classes. For example, the distribution for class 16 (from 3.7 to less than 3.86×10^3 m/s) would normally be associated with high density slabwood chips and not corewood. In contrast classes 1 and 2 (1.35 to less than 1.66×10^3 m/s) contained very short fibres, even shorter than would normally be associated with corewood. Previously available information, based on basic density information, had indicated that corewood samples of the type employed in this trial should have been reasonably homogeneous in relation to fibre quality. The results of the study clearly showed this not to be the case. Similarly, with regard to WZST strengths, strengths greater than 15km are normally associated with high density, slabwood chips, and some of the core samples in the study had WZST strengths as high as 16.5km.

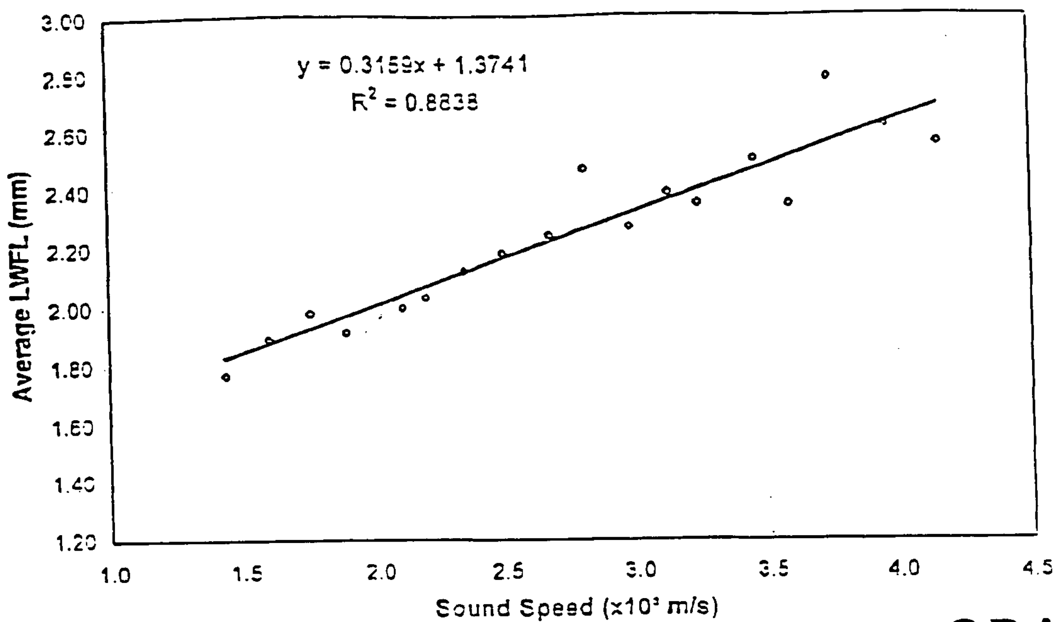
Although the study results were obtained using corewood, it is considered that fibre properties in corewood would translate to fibre properties in the outer wood in a predictable manner. For example, a peeler core in a higher sound class (yielding relatively long, strong fibres) would be expected to have had outer wood with even greater fibre length and strength. However, the rate of change in fibre properties on moving from corewood to outer wood may vary from tree to tree, due to differences in genetic, site or silviculture factors.

Therefore, the exact regression equation relating sound speed through a log to expected pulp characteristics may vary from that determined in this example for radiata pine corewood. For example, the regression equation between whole log sound speed and the properties of pulp made from the outer or slabwood of these logs (i.e. arising as saw mill chips) is likely to be different to that described here. However, the basic form of relationship will be the same. Similarly, the

Table II: Sound Class Data

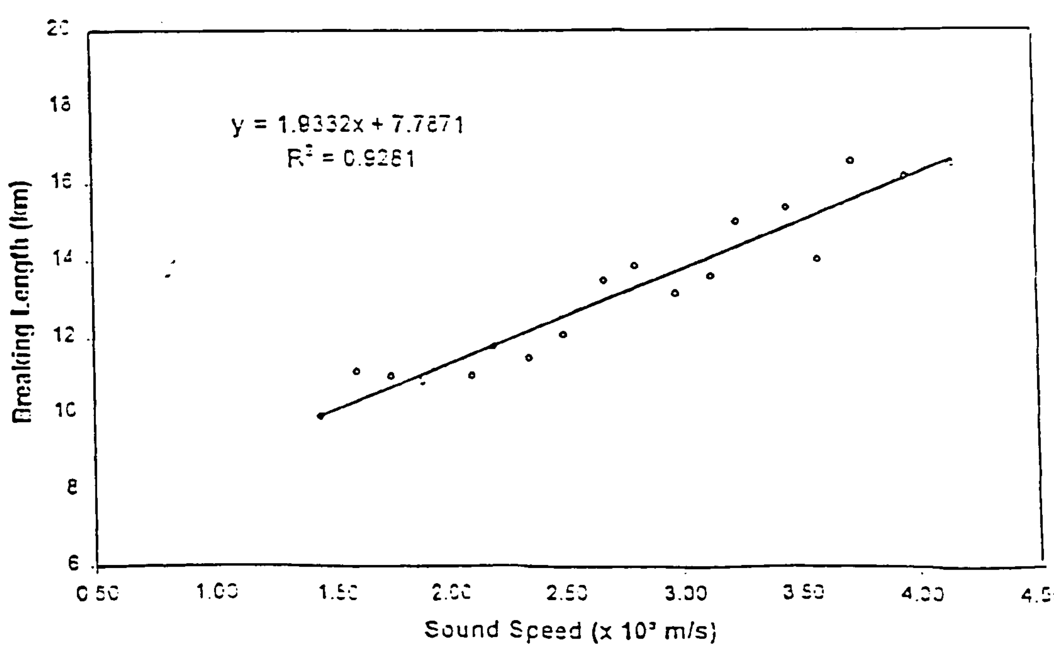
Class Limits ($x 10^3$ m/s)	Average Velocity ($x 10^3$ m/s)	Number of Cores	Cumulative Percentage
1.35 – 1.50	1.44	2	0.8
1.50 – 1.66	1.60	2	1.6
1.66 – 1.82	1.75	12	6.4
1.82 – 1.97	1.89	16	12.8
1.97 – 2.13	2.11	15	18.8
2.13 – 2.29	2.20	24	28.4
2.29 – 2.44	2.35	22	37.2
2.44 – 2.60	2.50	29	48.8
2.60 – 2.76	2.68	34	62.4
2.76 – 2.92	2.81	21	70.8
2.92 – 3.07	2.98	23	80.0
3.07 – 3.23	3.13	10	84.0
3.23 – 3.39	3.24	15	90.0
3.39 – 3.54	3.45	10	94.0
3.54 – 3.70	3.59	5	96.0
3.70 – 3.86	3.74	4	97.6
3.86 – 4.01	3.96	4	99.2
4.01 – 4.17	4.16	2	100

Average LWFL versus sound speed for each of the 18 sound classes



GRAPH 1

Wet ZST Breaking Length versus Average Sound Speed



GRAPH 2

exact regression equation may also vary for logs of different tree species or which have substantial differences in the relative proportions of outerwood to corewood.

While the description is made with specific reference to an example involving radiata pine, it is to be appreciated that the invention is not limited to any particular tree species and, subject to the above comments concerning calculation of specific regression equations, it is anticipated that the method will be equally applicable for other species.

An example of the commercial application of velocity of sound for pulp log sorting is shown in Figure 2.

Acoustic wave testing of logs can occur both at the log landing adjacent to harvesting operations and at central log handling facilities, such as the log yard of a pulp mill. Testing at log landings has the advantage that both saw logs and pulp logs can be characterised by sound speed before decisions are made as to which processing facility they are sent to. For example, the sound speed measurement can be used to select saw logs of superior stiffness for sawing into structural grade timber. However, testing at the log landing will most likely be a manual operation using hand-held stress-wave timers and so may be rather labour intensive.

Pulp logs X which have already been tested for sound speed at the log landing, on arrival at the pulp mill log yard, can be immediately allocated to a particular log pile A, B, C, based on this characteristic. Nevertheless, it may be preferable for some processing operations to have automated sound speed measurement at a central log handling facility. The pulp mill log yard would be one such facility in which large numbers of logs can be tested and segregated into different log piles according to sound speed.

All logs arriving at the central log handling facility would be received on a landing which would automatically convey them into the stress wave testing centre 10. Automatic stress-wave testing would involve equipment which could grip each log, measure its length, sense the position of one or both log ends, and

then automatically apply the acoustic wave transit time measurement. The log would then be "bucked" off the main chain conveyor 11 onto one of several decks 12 according to the measured velocity of sound. Logs with speeds within given ranges would be classified according to the pulp mill's product requirements. Log stackers would then move the logs from each landing into separate log piles A, B, C, each representing a separate sound speed class.

The logs would then be processed in chippers 13, 14. Chipping operations at pulp mills can typically feed chips onto several different chip piles 15, 16, 17, 18. Chips are then reclaimed off these piles and fed into the various pulp mill processing lines 19, 20, 21. Different pulping lines may be dedicated to different product types or a pulping line may swing between different pulp grades using a campaigning strategy. In either case, chips can normally be fed into a pulping line from any of the different chip piles.

Pulp mills also receive a large amount of their wood supply in the form of wood chips Z, which are produced at saw mills from the waste slabwood taken from the outside of saw logs. If a saw log has been tested for sound speed before sawing, such that logs of a given sound speed class can be sawn as a batch, then the chips arising from the slabwood would already be characterised as to their end-use suitability for processing into pulp. On arrival at the pulp mill, such "sound-speed characterised" saw mill chips 22 could be blended into the appropriate chip pile 15, 16, 17, 18.

It will be appreciated that Figure 2 is simply one example of a possible pulp log sorting process involving the method of the present invention, and other examples might include any number of categories of logs, chippers, chip pile categories and pulp line

In conclusion, the strong relationship identified between velocity of sound in peeler cores and both fibre length and fibre strength has significant commercial application for the processing of wood in the pulp industry. Currently, pulp and paper mills normally utilise the residues from solid wood processing, such as

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chips from the slabs on the outside of the sawn logs, and logging residues (top logs and low grade logs that arise during harvesting operations). There is very little segregation of wood in pulp and paper manufacture, and the only basis for such segregation in the past has been using basic density as a crude indicator. By sorting wood for pulping according to acoustic analysis (i.e. speed of sound characteristics) the efficiency of wood processing in the manufacture of specified pulp and paper products can be substantially improved.

While the invention has been described with specific reference to kraft pulp production, the method of log segregation of the invention could equally apply for other forms of pulp manufacture, such as semi-chemical, chemi-mechanical and mechanical pulping, as will be apparent to those skilled in the art.

The process of log segregation of the invention could also be of value for wood-fibre-based processes other than pulp and paper manufacture in which fibre length/strength characteristics may be important. One particular example would be fibre-board production, e.g. medium density fibre-board.

Where in the foregoing description reference has been made to specific components or integers of the invention having known equivalents then such equivalents are herein incorporated as if individually set forth.

Although this invention has been described by way of example and with reference to possible embodiments thereof it is to be understood that modifications or improvements may be made thereto without departing from the scope or spirit of the invention.

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By its Attorneys
BALDWIN SHELSTON WATERS

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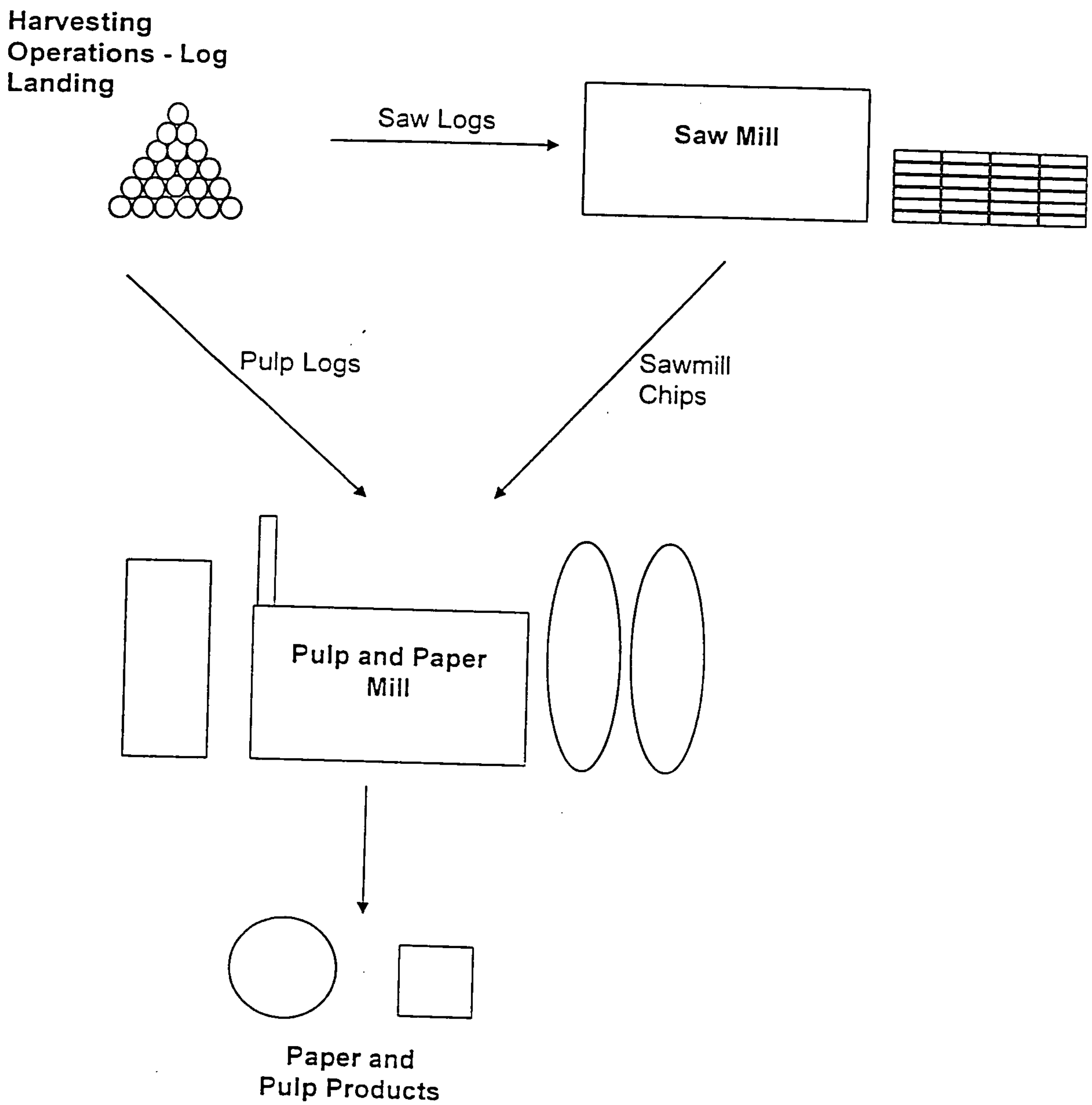
Harvesting Operations - Log Landing
Saw Logs
Saw Mill
Pulp Logs
Sawmill Chips
Pulp and Paper Mill
Paper and Pulp Products

FIGURE 1

PROVISIONAL

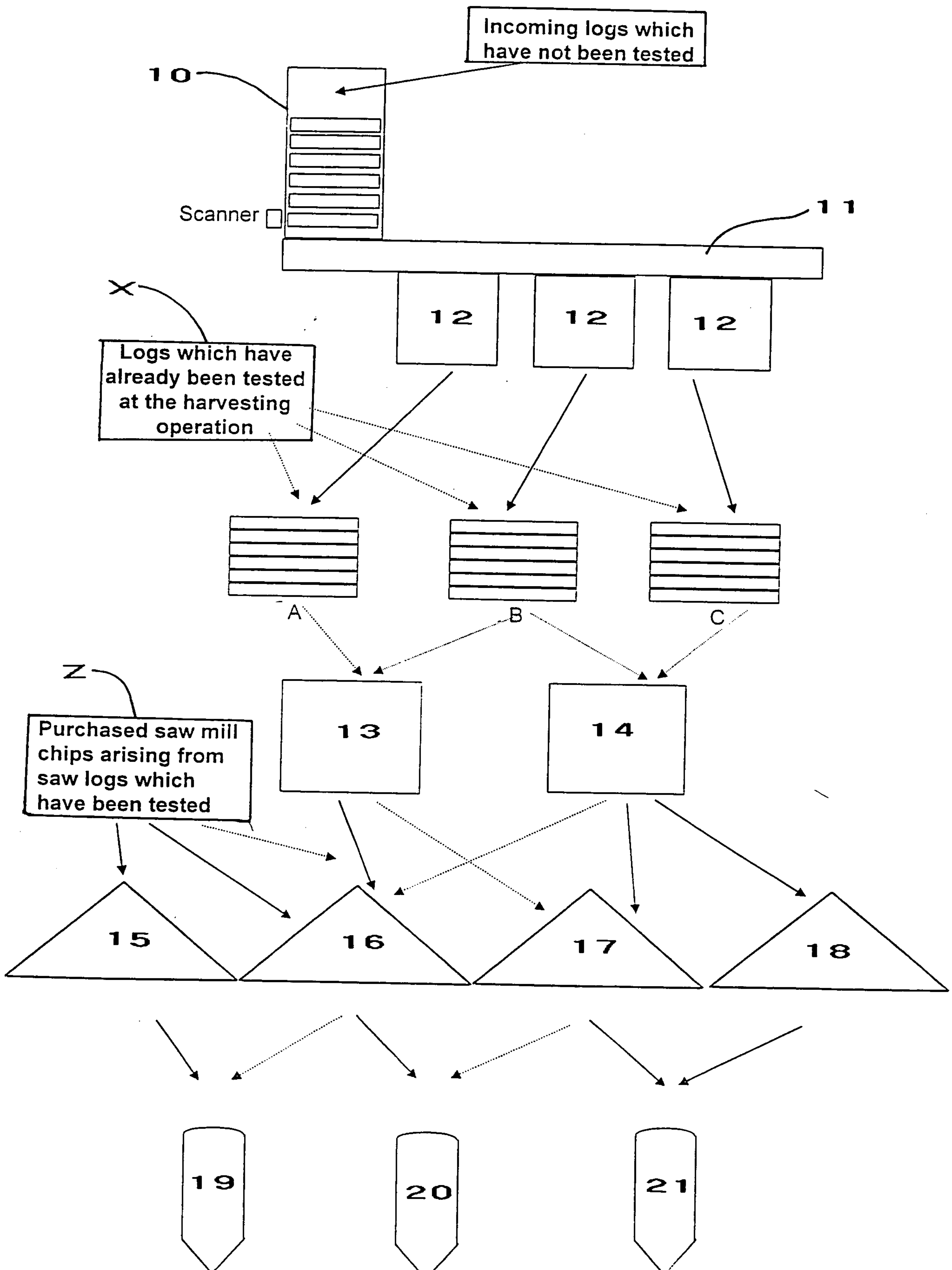

FIGURE 2